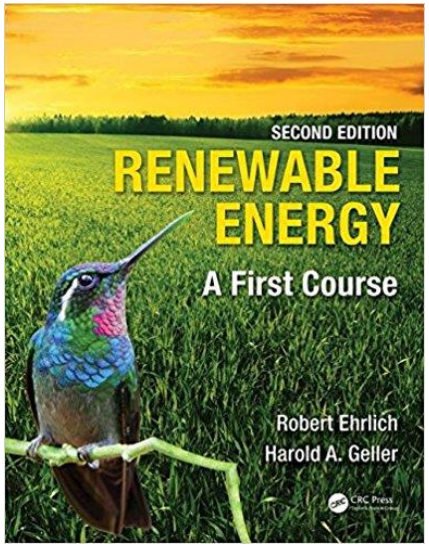

Chesapeake Section

The Physics of Renewable Energy

By
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Observatory Director
NASA/JPL Solar System Ambassador

SOLAR SYSTEM AMBASSADORS

GEORGE MASON UNIVERSITY

Abstract

Over the past decade, there has been an ever increasing interest in the development of renewable energy resources. Renewable energy is defined as "that energy that is collected from renewable resources, which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves, and geothermal." We will discuss the structure and implementation of a physics department course in renewable energy, which has become a portion of the renewable energy minor in the department and a master's level program run as an interdisciplinary master's program across physics, engineering and environmental sciences.

Reflection Question

What first got you interested in physics?

My Personal Reflection

- I still recall my father giving me two strong magnets.
  - He demonstrated how difficult it was to push them together unless they were the opposite poles.
    - I tried to tell how it was that I could not push them together, easily.

Physics Education Research Findings

- **Textbooks present a fragmented and sometimes misleading view of energy.**
  - **Energy is said to be "invented," and "abstract."**
  - **Energy can be "converted" to different "forms."**
- **"Students do not find energy to be very useful, even for prototypical school science phenomena."**

Physics Education Research Findings

- **"National science standards present a problematic view of energy."**

  From the opening sentence of the energy section in the AAAS/Project 2061 Standards:

  "Energy is a mysterious concept…."

Physics Education Research Findings

- **Students have an incoherent view of energy.**
  - **Potential energy is often ignored.**
    - **"Just a number"**
    - **"An invented quantity"**
    - **Potential energy is not *actual* energy.**
    - **It often is thought to have nowhere to exist, so it cannot really exist.**

Physics Education Research Findings

- Students have an incoherent view of energy.
  - Energy can be "produced."
  - Energy conservation only weakly constrains student thinking. It does not force inferences.
- Energy is not *useful* to students in describing and explaining natural phenomena.
  - Often have to be prompted even to invoke it!

Recommendations

- **Energy should be presented as a single concept.**
  - **Energy does not come in different "forms." It is only stored in different things.**
  - **There is only one kind of energy: Energy**

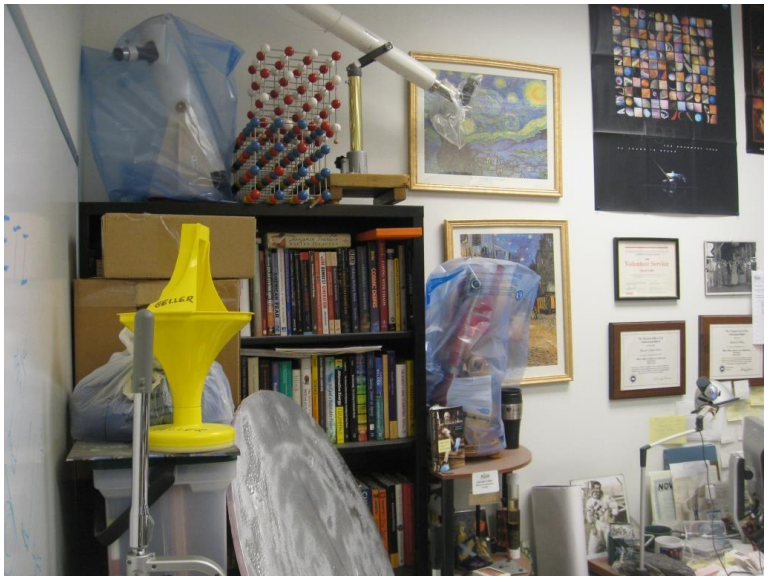
Physics Concepts in Renewable Energy

- Fundamental concepts of energy
  - Nuclear Fission; Nuclear Fusion
- Measurements and units of energy
- Energy sources
  - Solar energy; Hydroelectric power; Wind power; Ocean thermal energy conversion; Geothermal power; Tidal energy; Wave energy; Nuclear energy
- Nuclear weapons
- Thermodynamics
  - Energy conservation
- Modes of transportation
- The atmosphere
  - Ozone layer
  - Greenhouse Gas Effect

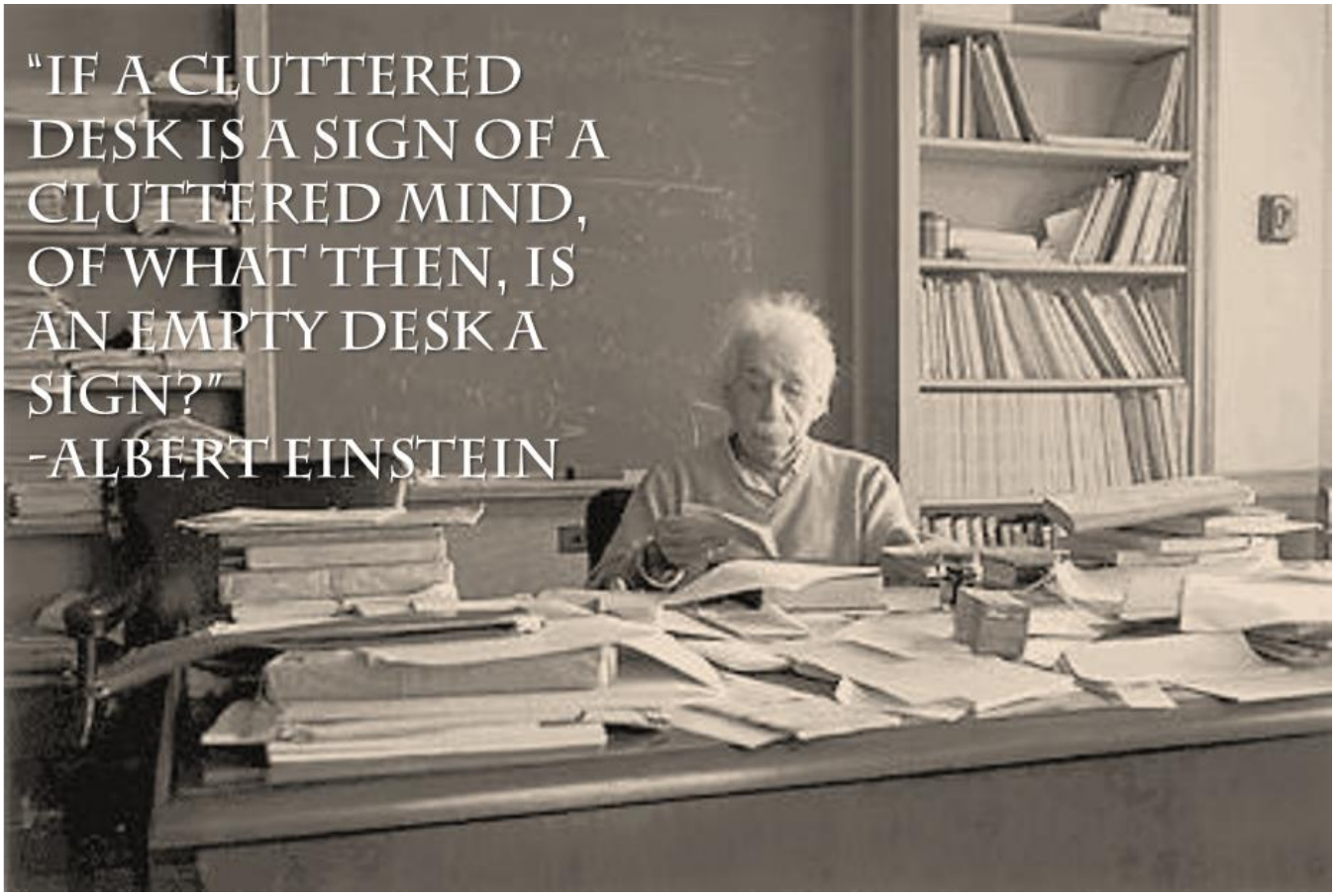
"Lecture" Mechanics

- Small class (~20) environment
- Reading assigned before class (~"flipped")
- Personal response system used to 'quiz' in class
  - Formative assessment
- In class group effort
  - Break up into groups of 3 or 4 with leader & recorder
  - Provide 3-5 thoughtful questions requiring critical thinking and scientific reasoning
  - Share out results
- Homework assignments
  - Energy-related simulations
  - Nuclear power plant; energy efficient design; etc.

I have a Cluttered Office



Remember What Einstein Said



Don't Forget

- Units of length, mass and time
- Metric Prefixes
- Relationship of Mass, Volume and Density
- The Scientific Method
- Speed, velocity, acceleration
- Force
- Falling objects
- Newton's Laws of Motion
- Newton's Law of Universal Gravity

Main Concepts For Understanding Energy

- Work
- Potential Energy
- Kinetic Energy
- Conservation of Energy
- Types/Sources of Energy

Work = Force times distance

- Definition of work
  - "work is equal to the force that is exerted times the distance over which it is exerted"
  - work in Joules =
    - force in Newtons * distance in meters
  - W = f * d

Question for Thought

- A spring clamp exerts a force on a stack of papers it is holding together. Is the spring clamp doing work on the papers?
  - Yes
  - No

- If the spring clamp does not cause the paper to move, it is not acting through a distance and no work is done.

Power - Work per unit time

- Power defined
  - "power is the amount of work done divided by the time it takes to do that work"
  - power in Watts = work in Joules / time in seconds
  - $P = W / t$

Question for Thought

- A lamp bulb is rated 100 Watts. Is there a time factor included in the rating?
  - No
  - Yes

- Because a time factor is in the rating. A watt is a unit of power, and power is work per unit time. A 100 W light bulb uses energy at a rate of 100 J per s.

Question for Thought

- A kWhr is
  - A a unit of work
  - B a unit of energy
  - C a unit of power
  - D More than one of the above is true.

- A kWhr is a unit of work, and since energy is the ability to do work, it is also a unit of energy. In terms of units, a watt is a joule per second, and an hour, as a second, is a unit of time. The time units cancel, leaving a unit of a joule, which can be used to measure either work or energy.

Kinetic Energy

- Definition
  - "Kinetic energy equals the mass of the moving object times the square of that object's speed, times the constant 1/2."
  - kinetic energy in Joules = 0.5 * mass in kilograms * speed in meters per second * speed in meters per second
  - K.E. = $0.5 * m * v^2$

Question for Thought

- Is work related to energy?
  - Yes
  - No

- Energy is the ability to do work, and doing work on something gives it energy.

Question for Thought

- Does a person standing motionless in the aisle of a moving bus have kinetic energy?
  - Yes
  - No

- Relative to the bus, the person has no kinetic energy because the person is at rest relative to the bus. Relative to the ground, however, the person does have kinetic energy because the person is moving with the same speed as the bus.

Question for Thought

- A joule of work and a joule of energy are fundamentally the same?
  - Yes
  - No

- A joule is one Newton-meter. A joule of work is from a force acting through a distance while a joule of energy is the ability to perform one joule of work. The use of the same unit means that work and energy are fundamentally the same thing.

Potential Energy

- Definition
  - "gravitational potential energy of any object equals its weight times its height above the ground"
  - gravitational potential energy in Joules = mass in kilograms * acceleration due to gravity * height in meters
  - P.E. = m * g * h

Question for Thought

- What is the relationship between the work done while moving a book to a higher bookshelf and the potential energy that the book has on the higher shelf?

- The work done is equal to the increase in gravitational potential energy.

Question for Thought

- Compare the energy needed to raise a mass 10 meters on Earth to the energy needed to raise the same mass 10 meters on the Moon. Explain the difference, if any.

- The energy required is less on the moon because the weight of the object (the downward force due to gravity) depends upon the force of gravity, which is less on the moon than on the earth. Less energy is needed to do the work of raising the mass on the moon, and the elevated object on the moon has less potential energy as a consequence of the work done.

Question for Thought

- What happens to the kinetic energy of a falling book when the book hits the floor?
  - A The kinetic energy is destroyed.
  - B The kinetic energy is converted to heat only.
  - C The kinetic energy is converted to heat and sound.

Mass as Energy

- Definition
  - "every object at rest contains potential energy equivalent to the product of its mass times the speed of light squared"
  - energy in joules = mass in kilograms * speed of light in meters per second * speed of light in meters per second
  - $E = m * c^2$

Energy Interchangeability

- Potential Energy
  - gravitational
  - chemical
  - elastic
  - electromagnetic
- Kinetic Energy
  - moving objects
  - heat
  - sound and other waves
- Mass
  - $E = m * c^2$

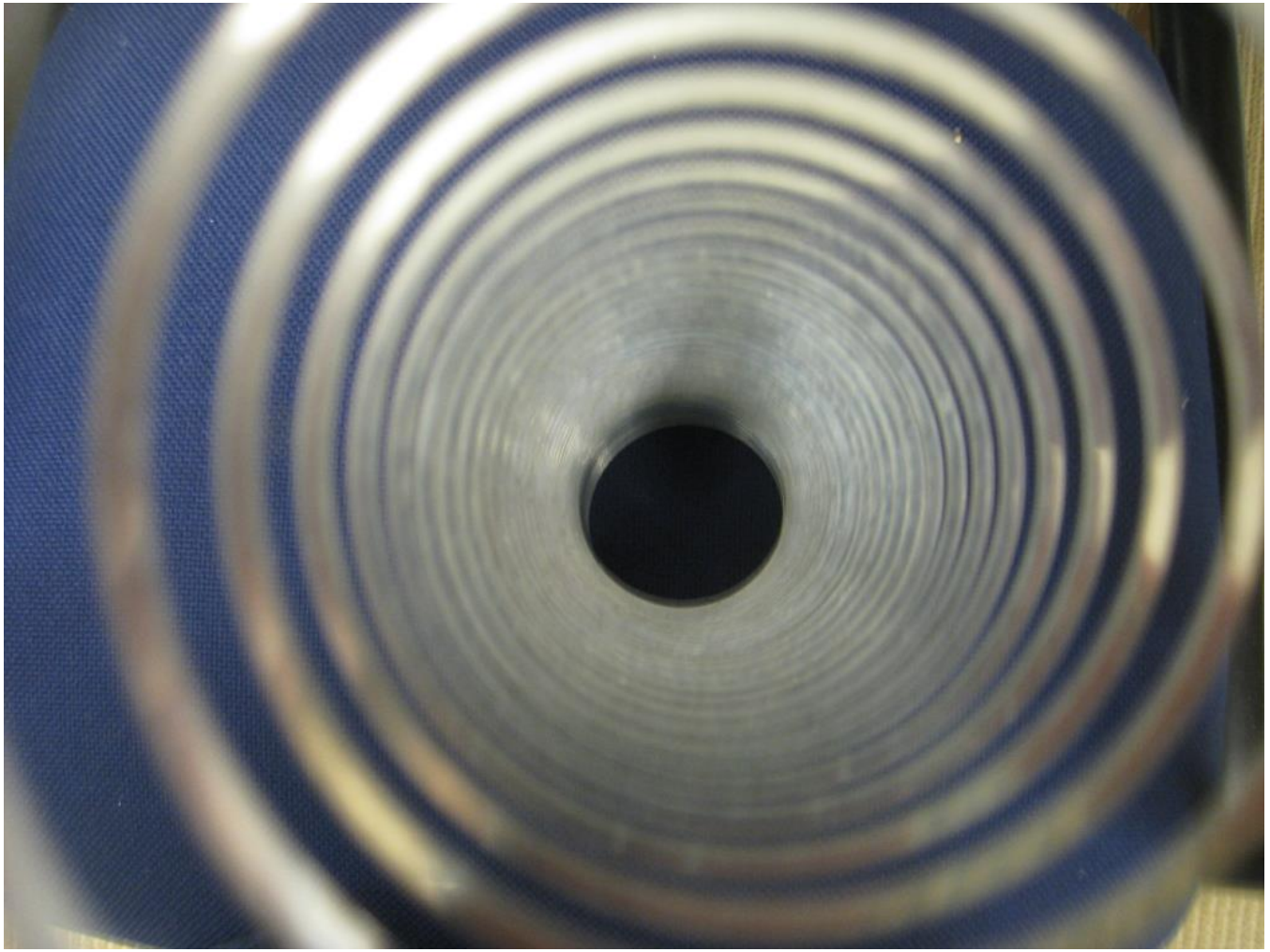
Energy is Conserved

Question for Thought

- If energy cannot be destroyed, why do some people worry about the energy supplies?

- Energy is eventually converted into unrecoverable radiant energy, so new sources of convertible energy must be found in order to continue performing useful work.

What is this?



Now You Know

A Slinky – it can be used to demonstrate

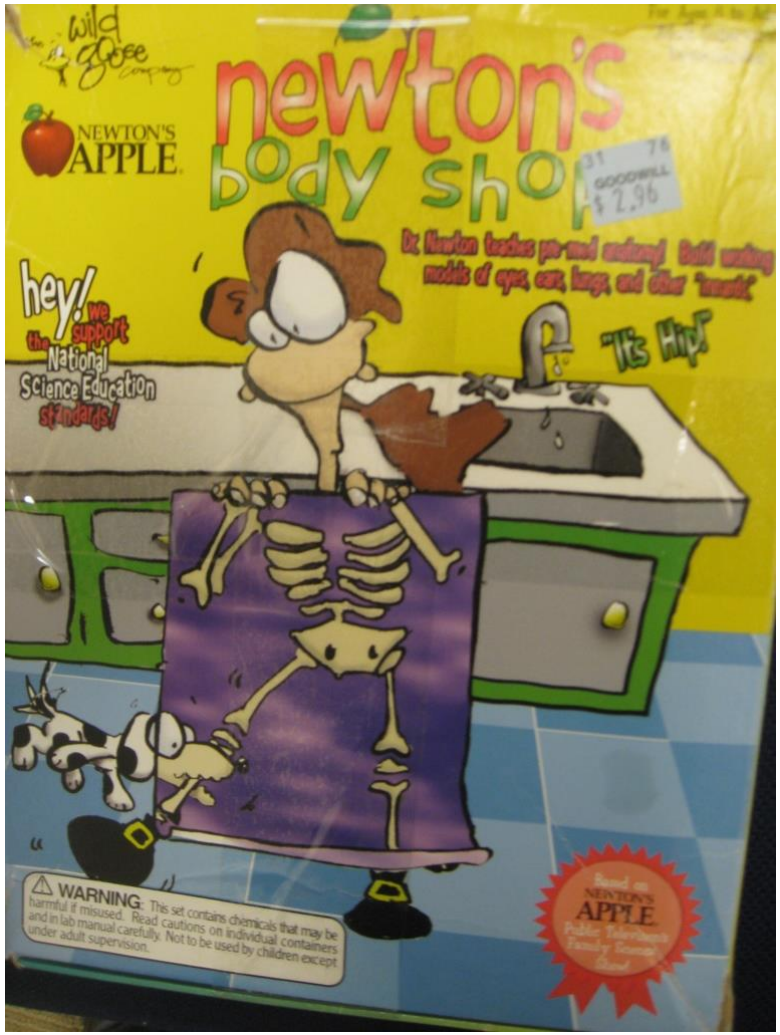
- Longitudinal Waves
- Transverse Waves
- Standing Waves
- Hooke's Law (springs)

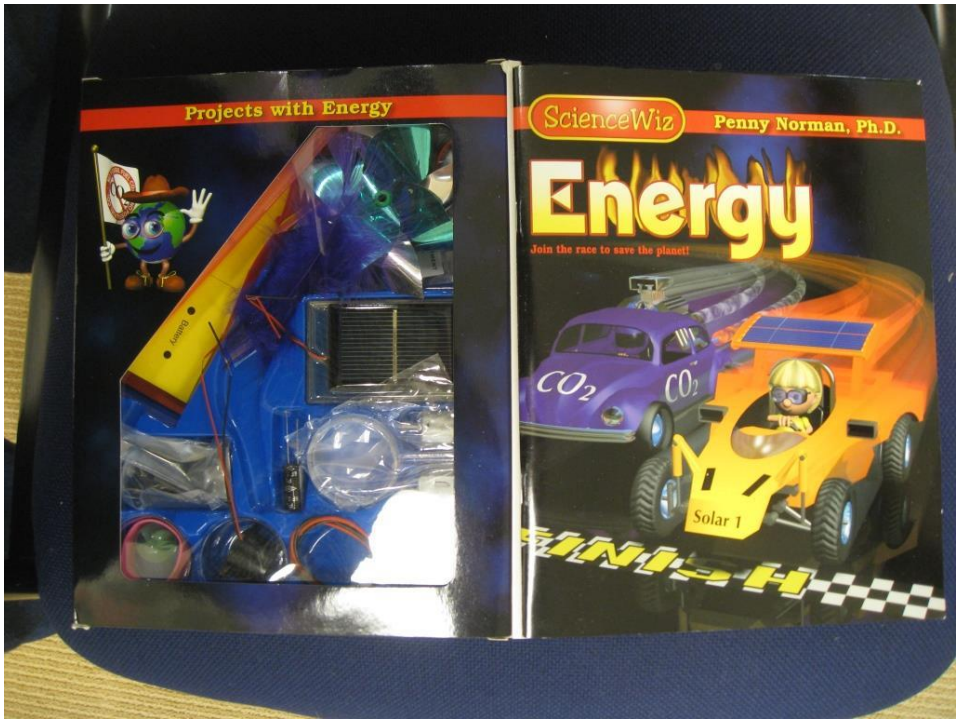
How About This?

Supernova (balls on a stick) can be used to demonstrate

- Supernova collapse and explosion processes
- Newton's Third Law
- Conservation of Energy

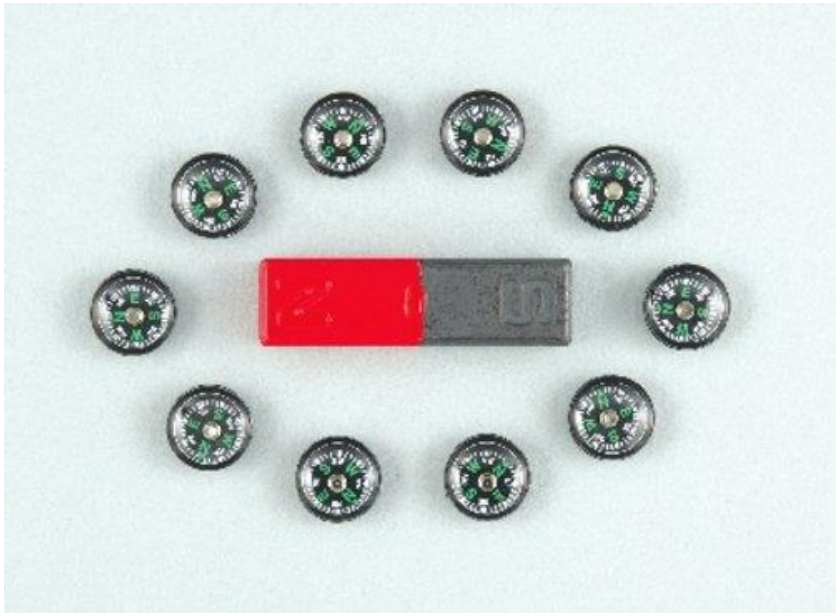
Or These?


Wild Goose Company
NEWTON'S APPLE
newton's body shop
GOODWILL $2.96
hey! We support the National Science Education standards!
"It's Hip!"
WARNING: This set contains chemicals that may be harmful if misused. Read cautions on individual containers and in lab manual carefully. Not to be used by children except under adult supervision.
Based on NEWTON'S APPLE


Projects with Energy
ScienceWiz
Penny Norman, Ph.D.
Energy
Join the race to save the planet!
CO_2
CO_2
Solar 1

Magnets

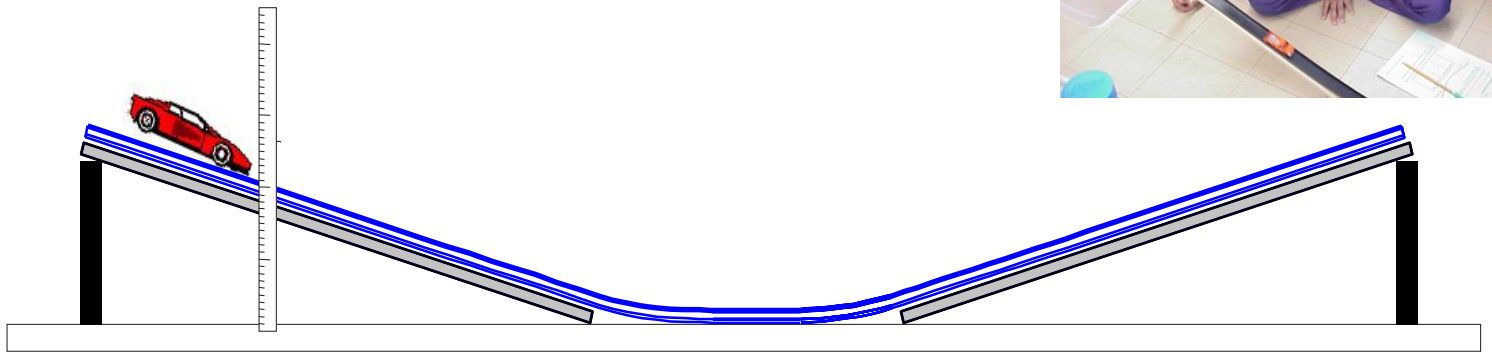
Compass (magnetic)



Rubber Bands

Activity with Half Ball and Hot Wheels

Bounce
"half" ball

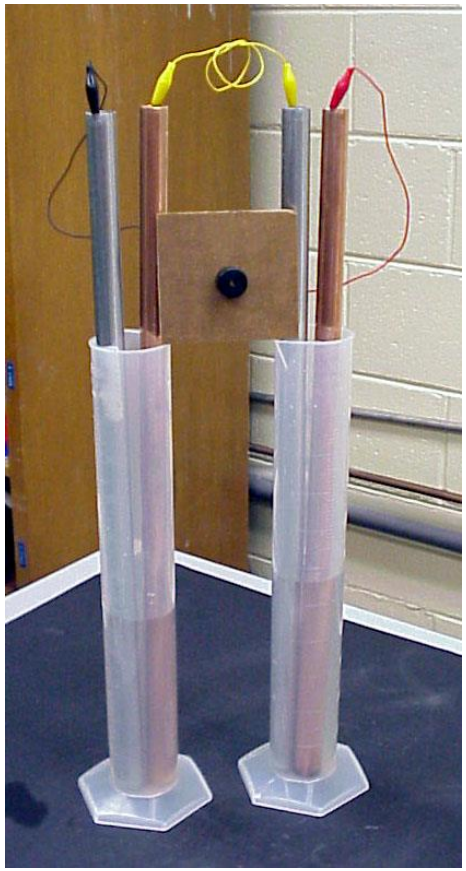


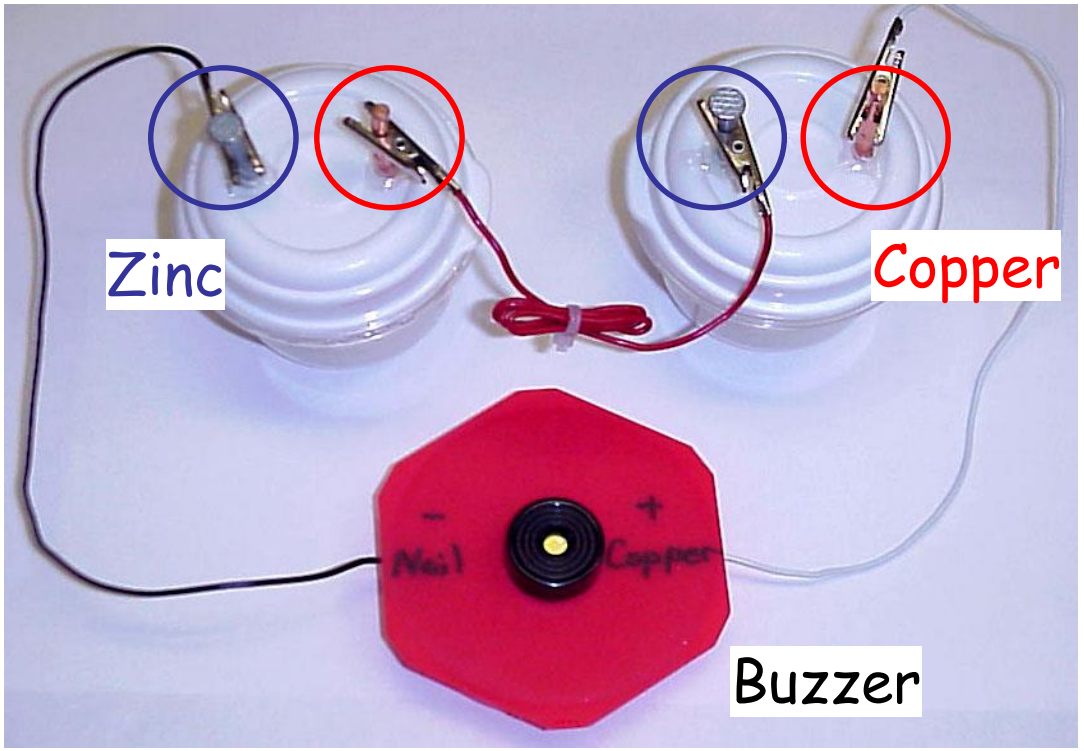
Beginning
Height

Measure Ending Height

- Develop teamwork, graphing, and prediction skills.
- Measure beginning and ending heights of released car to discover loss of energy.

Activity with Salt Battery

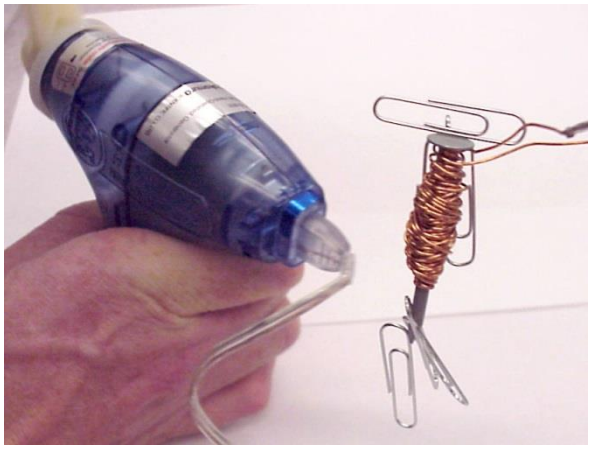


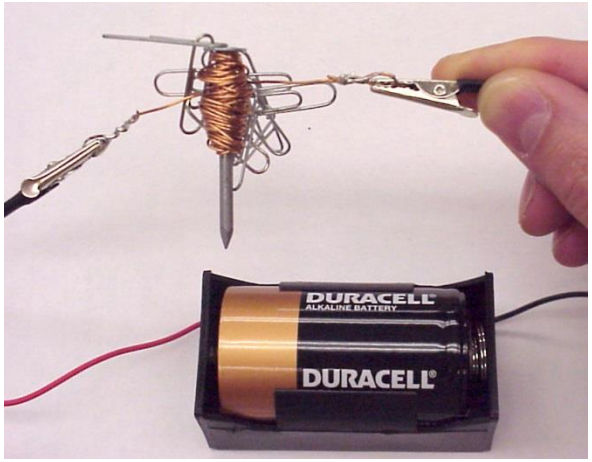


- Construct salt-water battery using copper and zinc electrodes to make buzzer work!

Activity with Electromagnets

Mini-electromagnet

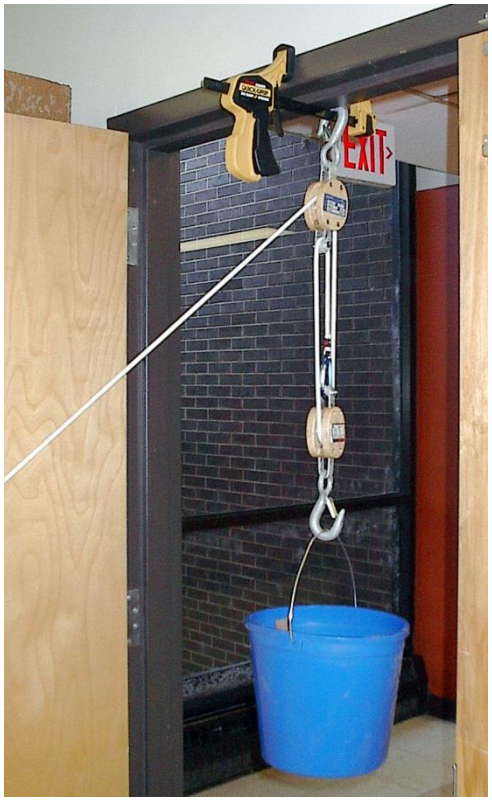




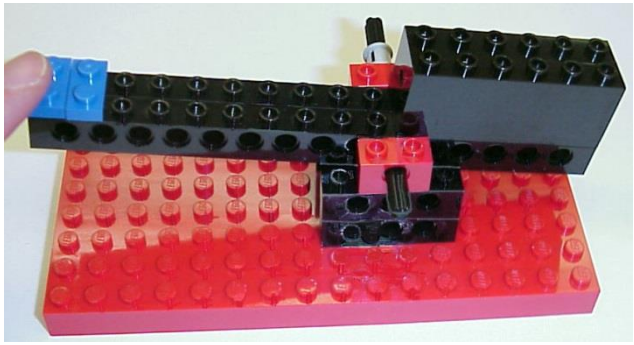
Loudspeaker

- Make electromagnet with wire wrapped around nail and "power" with generator or battery.
- Make loudspeaker using electromagnet, cup, and radio.

Activity with Simple Machines



Pulley System



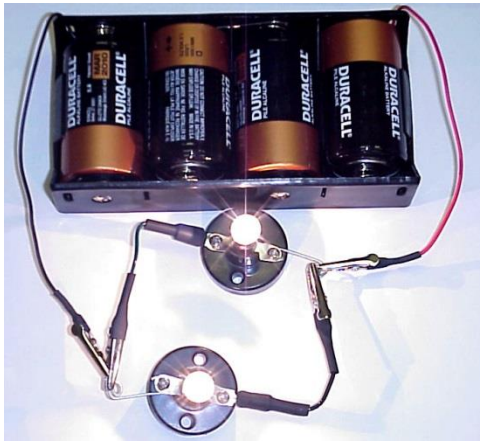
Construct Lego Lever

Identify Tools as Simple Machines

Activity with Electrical Circuits

Series Circuit

Parallel Circuit



- Build series and parallel circuits with lightbulbs and measure voltage using a meter.
  - What happens when one bulb is unscrewed?
  - Which bulbs are brighter?

Activity with Magnets

Magnet

- Predict whether items are magnetic or not.
- Draw magnetic "field" lines formed by iron filings around a magnet.

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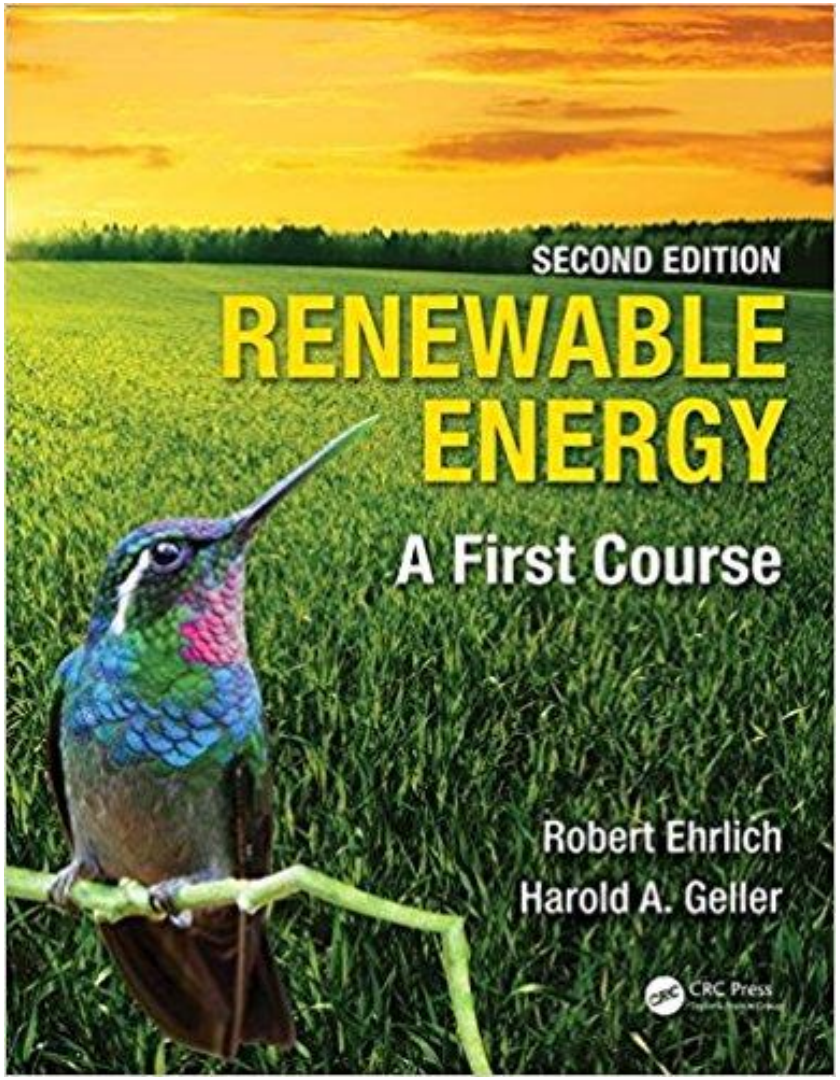
Post-Mordem Notes

- Interdisciplinary science courses in Honors College to end
  - Spring 2016 last semester for courses
  - Laboratory space was biggest issue
- Ehrlich (retired) and Geller (not retired) under contract to produce 2nd edition of Renewable Energy textbook
  - 2nd edition expected November 2017

Renewable Energy Textbook



- First edition
  - 2013
    - Robert Ehrlich
- Second edition
  - November 2017
    - Robert Ehrlich
    - Harold Geller

Acknowledgements

- The students of HNRT 228 Energy and the Environment
  - Spring 2014; Spring 2015; Spring 2016
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  - Spring 2017; Fall 2017
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